Minimum Operational Performance Standards for Aviation Night Vision Imaging Systems

1.0 Purpose

1.1 Introduction

This document contains minimum operational performance standards (MOPS) for aviation Night Vision Imaging Systems (NVIS) that are used to supplement night VFR operations. These standards specify system characteristics that should be useful to designers, manufacturers, installers and users of the equipment.

Compliance with these standards is recommended as one means of assuring that the equipment will perform its intended function(s) satisfactorily under all conditions normally encountered in routine aeronautical operations. Any regulatory application of this document is the sole responsibility of appropriate governmental agencies.

Section 1.0 of this document provides information on purpose and scope needed to understand the rationale for equipment characteristics and requirements states in the remaining sections. It describes typical equipment applications and operational goals, as envisioned by the members of Special Committee 196, and establishes the basis for the standards stated in sections 2.0 and 3.0. Definitions and assumptions essential to proper understanding of this document are also provided in this section.

Section 2.0 contains general guidance and minimum performance standards for the equipment. These standards specify the required performance under standard operating and environmental conditions. Also included are recommended bench tests procedures necessary to demonstrate equipment compliance with the stated minimums.

Section 3.0 describes the requirements for installed equipment performance. Tests for the installed equipment are included when performance cannot be adequately determined through bench testing, as described in section 2.

Section 4.0 describes the operational performance characteristics for equipment installations and defines conditions that will assure the equipment user that operations can be conducted safely and reliably in the expected operational environment.

Section 5.0 describes the continued airworthiness procedures to ensure the equipment and equipment installation continue to meet the minimum performance standard once in operational use.

Appendix A is a list of abbreviations and acronyms recommended for use with NVIS and associated documents. Appendix B contains a bibliography and a list of all references cited in this document. Appendix C has a list of all "shall" requirements in the body of this document (summarized for the conveyance of the applicant and test team). Appendix D contains NVIS lighting color limits, while Appendix E discusses spectral radiance, luminance, and illumination measuring equipment. Appendix F contains sample calculations used to determine NVIS compatibility.

The word "equipment," as used in this document includes all components and features necessary for the system to properly perform its intended function(s). Standards for design and implementation of optional features, beyond those required for a minimum NVIS, only apply if those features are implemented. This MOPS also include minimum requirements for the operational environment for which these requirements are appropriate.

If the equipment implementation includes a computer software package, the guidelines contained in RTCA/DO-178B, *Software Considerations in Airborne Systems and Equipment Certification*, should be considered.

1.2 System Overview

The Aviation Night Vision Imaging System, herein referred to as NVIS, is a system which uses image intensifier tubes to produce an enhanced image of a scene in light conditions too low for normal navigation and pilotage. NVIS equipment may have the physical form of image intensifier tubes that can either display an intensified image on a phosphor screen in the user's direct line of sight or project the intensified image on a see through medium in the user's line of sight. Additionally, the NVIS equipment will be complemented by aircraft interior lighting that provides acquisition of aircraft interior information with the unaided eye without degrading the image intensification capabilities during night flight operations.

Figure 1-1 Night Vision Imaging System Diagram

1.2.1 Binocular Assembly

The binocular assembly contains two redundant monocular assemblies. It may house the adjustment mechanisms for interpupillary (eyespan) adjustment, eyepiece and objective lens focus, fore and aft adjustment, vertical adjustment, and the tilt adjustment. It may also contain a breakaway feature at its interface with the head or helmet mount.

1.2.1.1 Monocular Assembly

The monocular assemblies contain the electro-optical components that gather the available light, amplify that light and present that light to the human eye.
Each monocular consists of an objective lens, image tube, and eyepiece. Available light from the night sky and other sources is reflected off scene objects, creating the input to the NVIS.

The dimly-lit image is brought into focus on the image tube by the objective lens. The image tube uses a light-sensitive photocathode that emits electrons which are then amplified through a microchannel plate and then impinged on a phosphor plate to produce the final image. A fiber optic twist may be used to invert the final image "right-side" up. The intensified image of the dimly-lit object is now readily visible to the naked eye when viewed through the eyepiece.

1.2.1.2 Objective Lens Assembly

The objective lens assembly (See Figure 1.1) collects the available light and focuses it on the image intensifier assembly.

1.2.1.3. Image Intensifier Assembly

Image intensifiers greatly amplify available light to provide an imaging capability at night. The image may be inverted by the image intensifier, enabling a correctly oriented image to be presented to the eye to the user in some designs.

1.2.1.4 Eyepiece Lens Assembly

The eyepiece lens assembly magnifies the intensified image for viewing by the human eye, and can compensate for variations in user eyesight .

1.2.2 Power Source Assembly

The power source includes redundant battery compartments, with one battery (or set of batteries) as the primary source of power. Circuitry that monitors the voltage of the battery compartment in use shall trigger an operator visible low battery indicator, that will not create undo hazard to the operator or operation, when the battery (or set of batteries) in the compartment approach end of life.

1.2.3 Helmet or Head Mount

A detachable mount assembly serves as the mounting point for the binocular assembly. The mount may contain the system power connector, and may contain a breakaway feature for the goggle or the goggle plus mount.

1.2.4 Cockpit Viewing

The binocular shall allow the aircrew, by moving their eyes to look under the binocular, to view the cockpit instruments/displays with their unaided eyes.

(Add section on visibility of flight instruments – i.e., compatible lighting – for viewing with unaided eyes)

1.2.5 Ancillary Equipment

TBD

1.3 Operational Application

This MOPS establishes requirements for night VFR operating environment and infrastructure. The night vision enhancement system described in this MOPS is intended to be compatible with both existing and future airspace operations. Its capability, performance, and functions will provide an improvement in situation awareness to the user.

1.4 Intended Function

The fundamental purpose of NVIS is increase the amount light to the eye so one can visually acquire surface information that may be difficult to see at night. If the NVIS is intended to be used for functions beyond those addressed in this document additional requirements may apply.

For example, if the NVIS is intended for primary course guidance for IFR, it must meet the requirements described in the applicable references (e.g., RTCA DO-236; TSO C-129a; TSO 115; RTCA DO-208; RTCA DO-229B; AC 25-11, AC 23.1311, AC 27-1A, AC 29-2B, AC 120-29 or AC 120-28, as amended for Category I, II, or III). For a discussion of failure classifications see material in AC's 23.13091C, 27-1A, 29-2B, and 25.1309-1B.

1.5 Operational Goals (Ops concept needs to define)

The operational goal of NVIS is to improve the efficiency and safety of flight operations. The expected results of using NVIS include:

1. Increase situation awareness
2. Reduce operator workload
3. Enhances night visual acuity over that of unaided night VFR.

1.6 Assumptions and Scope

The design requirements and guidelines presented in this document assume several system characteristics and applications as listed below:

1. The NVIS improves night visual acuity, but it is not comparable to daytime visual acuity.
2. The visual acuity of NVIS cannot improve one's visual acuity if it is less than optimum.
3. Pilot can still maintain night VFR flight in case of NVIS failure
4. Design Guidance in this MOPS is intended for head-mounted NVIS presented to both eyes.

5. NVIS will provide independent intensifier tubes for each eye for redundancy and depth perception.
6. This MOPS provides a baseline NVIS, but does not contain an exhaustive or comprehensive list of shared display or imaging considerations (e.g. simultaneously depicting imaging data with symbology).
7. The user will have 20/20 corrected vision and if required, wear the appropriate corrective lenses while using NVIS.
8. The user will perceive those colors necessary for safe performance of airman duties.
9. Class B filtering is defined as the minimum acceptable filtering of the NVIS because it is compatible with either Class A or Class B cockpit lighting. Class A filtering is not compatible with Class B cockpit lighting; therefore, operators using Class A filtering must have Class A cockpit lighting.
10. Design Guidance in this MOPS does not specifically address:
    - Forward Looking Infrared Radar displays/devices
    - Synthetic or enhanced vision displays/devices
    - Attachable or fixed NVIS compatible Heads-Up Displays (HUD)

1.7 Test Procedures

The test procedures specified in this document are intended to be used as one means of demonstrating compliance with the performance requirements. Although specific test procedures are cited, it is recognized that other methods may be preferred. These alternate procedures may be used if they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

The order of tests specified, suggests that the equipment be subjected to a succession of tests as it moves from design, and design qualification, into operational use. For example, compliance with the requirements of Section 2.0 shall have been demonstrated as a precondition to satisfactory completion of the installed system test of section 3.0.

1.7.1 Environmental Tests

Environmental tests are specified in section 2.3. The procedures and their associated limit requirements are intended to provide a laboratory means of determining the electrical and mechanical performance of the equipment under environmental conditions expected to be encountered in actual aeronautical operations. Unless otherwise specified, the environmental test procedures contained in RTCA/DO-160D, *Environmental Conditions and Test Procedures for Airborne Equipment*, will be used to demonstrate equipment compliance.

1.7.2 Bench Tests

Bench test procedures are specified in section 2.4. These tests provide a laboratory means to demonstrate compliance with the requirements in section 2.2. Test results may be used by equipment manufacturers as design guidance for monitoring manufacturing compliance and, in certain cases, for obtaining formal approval of equipment design.

1.7.3 Installed Equipment Tests

The installed test procedures and their associated limits and requirements are specified in section 3.0. Although bench and environmental test procedures are included in the installed equipment tests, their successful completion is normally a precondition to the completion of the installed tests. In certain instances, however, installed equipment tests may be used in lieu of bench test simulation of such factors as power supply characteristics, interference from or other equipment installed on the aircraft, etc. Installed tests are normally performed under two conditions:

1. With the aircraft on the ground and using simulated or operational system inputs.
2. With the aircraft in flight using operational system inputs appropriate to the equipment under test.

Test results may be used to demonstrate functional performance in the intended operational environment.

1.7.4 Operational Tests

The operational tests are specified in Section 4.0. These test procedures and their associated limits are intended to be conducted by operating personnel as one means of ensuring that the equipment is functioning properly and can be reliably used for its intended function(s).

1.8 Definition of Terms

This section contains a definition of terms used that may have multiple, special, or unique meanings in this document.

NVIS: A system which uses image intensifier tubes to produce an enhanced image of a scene in light conditions too low for normal navigation and pilotage.

NVIS lighting compatibility: The aircraft interior lighting that provides acquisition of aircraft interior information with the unaided eye without degrading the image intensification capabilities of the NVIS during night flight operations.

Lighting system: All devices that emit or transmit light within the flight deck or other crew compartments.

Lighting subsystem: All devices that emit or transmit light within the flight deck or other crew compartments and are attached to the aircraft via a common dimmer control.

Class A: Any NVIS which utilizes the 625nm minus blue objective lens filters. Class A NVIS is not compatible with aviation red lights because of the overlap between the spectrum of red light and the sensitivity of Class A NVIS.

Class B: Any NVIS which utilizes the 665nm minus blue objective lens filters. Class B NVIS is compatible with NVIS red and therefore is compatible with properly filtered red lights and color electronic displays.

Leaky Green (Did we want to change to Class C?): A Class B type filter that possess characteristics such that light emitted from a Heads Up Display (HUD) employing a P-1, P-43, or P-53 phosphor CRT shall be transmitted to the image intensifier. Any HUD, when set to an operationally representative night brightness level, shall be readable through the operating night vision device containing Leaky Green filtered objective lenses.

Crewstation or compartment: All work stations or compartments within the aircraft in which the aircrew member is required to use NVIS in the performance of duties.

Interior lighting: All lighting within the aircraft including but not restricted to the following lighting systems:

- Instrument (primary & secondary)
- Console (primary & secondary)
- Emergency
- Warning, Caution, and Advisory displays and indicators
- Utility
- Controls (knobs, handles, push buttons)
- Compartment
- Work and inspection lights
- Jump lights

Light leaks: Visual evidence through the NVIS of light emitted from a component from areas which are not intended to be illuminated.

Direct View Image NVIS (Type I): Any NVIS which uses image intensifier tubes and displays the intensified image on a phosphor screen in the user's direct line of sight.

Projected Image NVIS (Type II): Any NVIS which uses image intensifier tubes and projects the intensified image on a see through medium in the user's line of sight. This configuration allows simultaneous viewing of the intensified image and visual cues such as HUD symbology.

NVIS radiance: NVIS radiance is the amount of energy emitted by a light source that is visible through NVIS. NVIS radiance is defined as the integral of the curve generated by multiplying the spectral radiance of a light source by the relative spectral response of the NVIS defined in Appendix E.

Contrast vs Contrast ratio: Contrast (C_L, C_I and C_{UL}) is one less than contrast ratio, may be defined as L_2/L_1.

CIE color coordinate system: The fundamental definitions of color are expressed in terms of the "standard observer" and coordinate system adopted by the International Commission on Illumination (C.I.E.) at Cambridge, England, in 1931 and published in the Journal of the Optical Society of America, Vol. 23, page 359, October 1933. Wherever chromaticity coordinates (x, *y*, z) appear in this document they relate to this system. The CIE 1976 uniform chromaticity scale (UCS) diagram is the CIE 1931 chromaticity diagram redrawn with the x and y axes subjected to a linear transformation as defined in CIE Publication 15, Supplement 2, 1978.

Rated drive condition: Rated drive condition(s) are the electrical power state(s) obtained by conformance to the allowable electrical characteristics (voltage, current, pulse width modulation, frequency, etc.) in MIL-STD-704 for the various lighting components or systems in meeting specified lighting levels.

Electronic and/or electro-optical displays: All displays capable of presenting a variety of different images on their screen; the displayed portrayals being generated through direct electronic modulation or through indirect electro-optical modulation of emitted, transmitted, or reflected light luminance levels, contrasts and/or chromaticities. These displays may present characters, numerals, symbols, graphics, or video. They are based on a CRT, a dot matrix technology, or a segmented design; and may or may not, be capable of portraying shades of gray.

Footlamberts (fL) X 3.426751 = candela per m^2 (cd/m^2) or (NITS)

Footcandles (fc) X 10.76391 = lumens per meter square or lux (lx)

Windscreen effects: **RS action item for definition**

Shall: In this document, the term "**shall**" is used to indicate requirements. An approved design must comply with every requirement, which can be assured by inspection, test, analysis, or demonstration.

Should: The term "should" is used to denote a recommendation or guideline that does not constitute a requirement.